Two-color, non-linear absorption of light in dye layers

Mark Warner [1,3], Richard Blaikie [2,3]
[1] Cavendish Laboratory, University of Cambridge, UK.
[2] Department of Electrical and Computer Engineering, University of Canterbury, NZ.
[3] MacDiarmid Institute for Advanced Materials and Nanotechnology, NZ.

Reversible, non-linear (saturable) absorption, is useful when deep penetration of light into dye layers, beyond the exponential depth in Beer's law, is required. An intense beam depletes the dye's ground state population, rendering much of the volume thereafter weakly absorbing to this colour. This creation of an excited state population of dye molecules renders the medium opaque to light of the colour that stimulates the back transition to the ground state. The first colour effectively switches the second, and *vice versa* in places where the second colour is more intense than the first. The crossover in dominance can be very sharp as the relative incident intensities vary. Thus a transverse spatial variation of the relative incident intensity of the two beams is very much sharpened through the dye layer by the competitive non-linear absorptions.

Two-colour, non-linear absorption is exploited to lithographically write structures [1,2] in the deeply sub-wavelength ($\sim\lambda/12$) region [3]. We model the intensity distribution, and the dynamics of its development, from the physics of the underlying two-colour interactions of intense light beams with dye layers [4]. When the resist layer on the other side of the dye layer is reached, the non-linearity has produced sharp transverse profiles of one colour at the expense of the other. The profile of the one colour of light to which the resist is sensitive is then recorded, producing sub-wavelength structures.

Polarisation effects are not susceptible to exact analysis, but finite element analysis reveals subtle, polarisation-dependent diffractive effects [5] on top of spatial narrowing due to non-linearity; see also the contribution of Foulkes and Blaikie at this conference. Our work is complementary to that approach, and provides an analytical benchmark.

[1] R. Menon and H. I. Smith, J. Opt. Soc. Am. **A23**, 2290 (2006)
[2] R. Menon, H.-Y. Tsai, and S. W. Thomas, Phys. Rev. Lett. **98**, 043905 (2007)
[3] T. L. Andrew, H.-Y. Tsai, and R. Menon, Science **324**, 917 (2009).
[4] M. Warner and R.J. Blaikie, Phys. Rev. **A80**, 033833 (2009)
[5] J. E. Foulkes and R. J. Blaikie, J. Vac. Sci. Technol. **B27**, 2941 (2009)